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Exogenous additives facilitate the fermentation of cigar tobacco leaves: improving sensory quality and contents of aroma components

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Abstract

The cigar market is growing rapidly in China. However, insufficient aroma value and quality, as well as confused subject fragrance were found in cigar tobacco leaves (CTLs), which has greatly restricted the development of Chinese cigar. In this study, several new and effective additives, including coffee, cocoa, ginger, cumin, and rhodiola rosea, were screened out for facilitating the fermentation process. Significant improvements on the aroma and sensory quality of CTLs were detected. The above-mentioned additives can increase the contents of total sugar, alcohols, alkenes, ketonic and acid aroma components in tobacco leaves. Besides, the content of representative aroma component, such as neophytadiene, increased by 1~2 times. Moreover, abundant new aroma components were introduced into CTLs. As a result, the performances on aroma richness, aroma and smoke characteristics, as well as aftertaste and combustion of CTLs were enhanced. The findings provide a promising strategy for enhancing sensory quality of domestic CTLs and the flourishment of Chinese cigar.

Keywords: cigar; tobacco fermentation; fermentation medium; sensory quality; aroma component.

Practical Application: This work developed several new additives to facilitate the fermentation of cigar tobacco leaves and enhance the sensory quality of cigar. The analysis of conventional chemical compositions and aroma components, as well as the sensory quality evaluation of tobacco leaves were conducted. Effective additives including coffee, cocoa, ginger, cumin, and rhodiola rosea, were screened out, which provides more choices for enhancing sensory quality of cigar.

1 Introduction

Cigar refers to the cigarette product made from cigar tobacco leaves (CTLs). Compared with the tobacco leaves for cigarette, CTLs possess the relatively more fragrant aroma and higher smoke concentration (Xu et al., 2021). With the economic development and blending of cultures around the world, the cigar market has been on the rise. Recent report showed that about 8.7 million U.S. adults smoked cigar in 2019 (Azagba et al., 2021). Besides, the sales of handmade cigars in China increased by 122% in 2020. However, the shortage of high-quality CTLs has greatly restricted the development of Chinese cigar (Zhang et al., 2021a). At present, most of high-quality raw materials for cigar product are produced from Dominican, Cuba, Nicaragua, Honduras, and so on (Yu et al., 2021). According to the comments from cigar consumers, improving the richness and value of aroma in Chinese cigar is urgent, since CTLs produced from China showed the noteworthy problems of weak aroma and single fragrance (Cai et al., 2019; Chen et al., 2019). For example, abundant scents such as bean and nut scents in cigar were favored by cigar consumers (Sun et al., 2020). Therefore, the optimization of cigar production processes is of great significance to improve cigar quality.

The production process of cigar includes cultivation, air-curing, fermentation, and rolling (Fan et al., 2016). Fermentation is an important process to improve the physical and chemical properties and smoking quality of CTLs, which could also weaken the pungent and sickening odors (Liu et al., 2022). Adjusting the fermentation conditions, such as temperature, humidity, time, and initial moisture content of tobacco leaves, was adopted in the traditional fermentation process, so as to alter biochemical reactions and improve the quality of tobacco leaves (Song et al., 2018). However, the effectiveness of improving sensory quality by traditional fermentation is limited. For most of CTLs, the defects of insufficient aroma value and quality, and confused subject fragrance cannot be ignored. Therefore, introducing exogenous additives in fermentation process is developed.

Theoretically, the flavor components carried by additives would enhance the aroma and quality of CTLs directly. Additionally, additives can also affect the growth and metabolism of microorganism, thus changing the aroma components and sensory quality of cigars (Zhang et al., 2021b). At present, there are very few studies on fermentation additives for cigars. Additives of green tea infusion, as well as diluted milk and rice wine were found to improve the sensory quality of CTLs, which show moderate smoke concentration, improved aroma quality, and comfortable aftertaste (Li & Zhang, 2016). In fact, the improvement of sensory quality is closely related to the change of aroma components in CTLs. Various aroma components were found in tobacco, including alcohols, alkenes, ketones, esters, nitroheterocycles, acids and so on. Different aroma component endows cigar different flavor profile, which could also affect the smoke and combustion characteristics of CTLs. Besides, several representative components, such as neophytadiene, solanone, and

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megastigmatrienone, show significant influence on the sensory quality. For example, neophytadiene and solanone account for 60~70% (w/w) of all aroma components, which could improve the mellowness and weaken the pungent odors of CTLs (Guo et al., 2021; Li et al., 2016). Therefore, adjusting the content and value of aroma components in fermentation process would be beneficial to improve the sensory quality of tobacco leaves.

In this study, several new effective additives of plant extracts and enzymes were screen out. The changes of sensory quality, major chemical contents, and aroma components with the additives were analyzed by panelists assessment, continuous flow analysis, and Gas Chromatography-Mass Spectrometry (GC-MS), respectively. This study provides a good example for enhancing the sensory quality of CTLs by fermentation, and enrich the availability of cigar tobacco raw material.

2 Materials and methods

2.1 Sample collection and tobacco fermentation

CTL samples used in this study contained three models of DX-4, DX-7, and CX-14. DX-4 and DX-7 were planted in De-yang (Sichuan, China) and CX-14 was planted in Shi-yan (Hubei, China). The tobacco samples were obtained after air-curing in a barn until the humidity of tobacco leaves reached 17~20%. Exogenous additives, including pepper, cumin, coffee, cocoa, matcha, ginger, chrysanthemum, rhodiola rosea, raspberry sauce, and kvass were purchased in a local market in Chengdu, China. α-amylase, pectinase, flavourzyme and the other reagents used were purchased from Chengdu Kelong Reagent Company and of analytical grade unless stated otherwise.

In a typic fermentation procedure, 4 g of pepper powder was mixed with 30 mL of de-ionized water. Then, 200 g of CTLs was weighted, and the pepper suspension was sprayed evenly on the surface of CTLs. The treated CTLs were transferred to linen bags and placed in a constant temperature and humidity incubator (Agilen, BINDER-KBF720). The fermentation was performed under the condition of 35 °C and 75% of relative humidity for 30 d. The fermented samples were obtained for sensory quality evaluation, aroma compositions, and other chemical components analysis. Additionally, pepper was replaced by cumin, coffee, cocoa, matcha, ginger, chrysanthemum, rhodiola rosea, raspberry sauce, or kvass, respectively. Besides, 0.2 g of enzyme (α-amylase, pectinase or flavourzyme) was also used in this study instead of pepper as an exogenous additive. For comparison, control samples without exogenous additive replaced by de-ionized water were obtained by the same procedure.

2.2 Sensory quality evaluation

The sensory quality evaluation was performed following the Standard Evaluation Form provided by Great Wall Cigar Factory (Sichuan, China). Sensory indicators are composed of scent components, and characteristics of offensive odors, aroma, smoke, aftertaste, and combustibility. A well-trained sensory panel consisting of five assessors majoring at cigar production was invited for the sensory quality assessment. The sensory descriptors were agreed upon by the panelists.

2.3 Determination of major chemical contents and aroma components

The contents of four conventional chemical components in tobacco, including total nitrogen (TN), nicotine (NIC), total sugar (TS), and reducing sugar (RS) were analyzed using a continuous flow analytical system (Alliance, FUTURA) according to the Tobacco Industry Standard YC/T161-2002 (TN), YC/T468-2013 (NIC), and YC/T159-2019 (TS and RS), respectively (Rong et al., 2021). Besides, GC-MS (Agilent, 7890B-5977) was used to determine the contents of aroma components in CTLs.

3 Results and discussion

3.1 Sensory quality evaluation

The results of sensory quality evaluation are shown in Figure 1 and Table 1. As we can see, for the control groups (adding

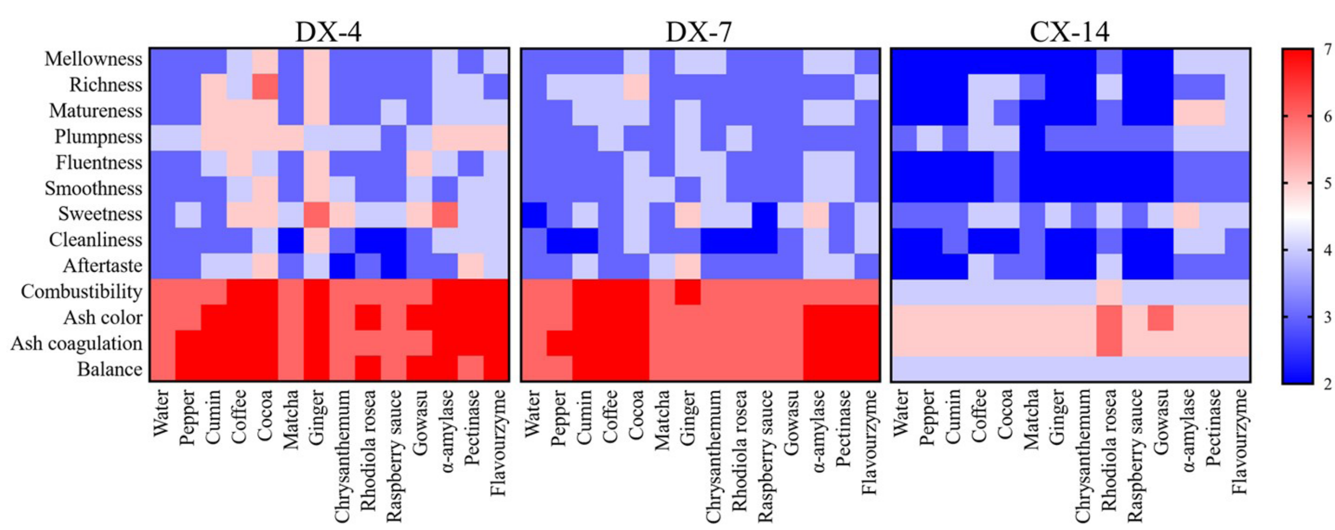

Figure 1. Effects of different additives on the aroma characteristics of CTLs.

Table 1. Effects of different additives on the sensory quality of CTLs.

Sample	DX-4	DX-7	CX-14
Water	This sample presents the low levels of flavor richness and smoke concentration, which accompanied by distinct ammonia, scorched, green and protein odors.	Moderate concentration and weak sweetness of smoke were found. The main flavor is confusing. Additionally, a low level of flavor richness and obvious protein odour in this sample were found.	This sample presents the low levels of flavor richness and smoke concentration, which accompanied by distinct scorched, green and protein odors. Besides, bad performances on combustibility and cleanliness of this sample were detected.
Pepper	The addition of pepper improved the sweetness and the level of ash coagulation of CTLs. However, other obvious optimizations in CTLs were not occurred.	The decreased cleanliness, increased flavor richness, and obvious scorched odour were found.	The concentration and plumpness of smoke were improved. However, the prominent spicy scent destroyed the original aroma characteristics and aftertaste of CTLs. Besides, offensive odor did not abate.
Cumin	The richness and matureness of aroma, as well as the plumpness and smoothness of smoke were improved. The color and coagulation of ash were also upgraded. The introduced cumin notes are in harmony with the autologous aroma of CTLs.	The relatively obvious style feature and sweet of aftertaste were found. The performances on maturity, flavor richness, and combustion were improved, but the cleanliness is decreased.	The main flavor, style characteristics, and weakened offensive odor were found clearly.
Coffee	The richness and matureness of aroma, as well as the plumpness, smoothness, sweetness, and concentration of smoke were improved obviously. Besides, the combustibility, color and coagulation of ash were also upgraded.	The performances on maturity, plumpness, and flavor richness were improved. Besides, the combustibility, color and coagulation of ash were also upgraded.	The richness and matureness of aroma, as well as the plumpness and sweetness of smoke were improved obviously. Besides, weakened offensive odor and improved aftertaste were found.
Cocoa	The ammonia odour is obviously weakened, and smoke is soft and delicate. The richness and matureness of aroma, as well as the fluentness and sweetness of smoke were improved. Besides, the cleanliness and aftertaste were upgraded. Combustibility, color, and coagulation of ash were also improved.	The richness and mellowness of aroma, as well as the smoothness and sweetness of smoke were improved. Besides, the aftertaste, as well as combustibility, color and coagulation of ash were also improved.	The offensive odor is obviously weakened. The richness and matureness of aroma, as well as the fluentness and sweetness of smoke were improved. Besides, the cleanliness and aftertaste were upgraded. Combustibility, color and coagulation of ash were also improved.
Matcha	Although the plumpness and sweetness of this sample were improved, the decreased cleanliness and distinct green odour were found.	Creamy scent was enriched, but the nut and bean scent were weakened. Additionally, the smoke performance and aftertaste were improved. Therefore, autologous aroma of CTLs was destroyed.	The cleanliness and aftertaste were improved, and the offensive odor were weakened slightly.
Ginger	The increase of spicy scent and obviously decrease of ammonia odour were detected. The mellowness, richness and matureness of aroma, as well as the smoothness and sweetness of smoke were improved. Besides, the aftertaste was upgraded, showing a polished harmony. The combustibility, color and coagulation of ash were also upgraded.	The increase of spicy scent was detected. The mellowness and matureness of aroma, as well as the smoothness and sweetness of smoke were improved.	The sweetness was improved. Overall, there was no obvious positive effects on aroma and smoke.
Chrysanthemum	The introduction of chrysanthemum slightly improved the smoothness and sweetness of smoke, but destroyed the original aroma characteristics and aftertaste of CTLs.	The performances on smoothness, mellowness, fluentness, and sweetness were improved, but the original aroma characteristics and aftertaste of CTLs were destroyed.	The sweetness was improved slightly. Overall, there was no obvious positive effects on aroma and smoke.
Rhodiola rosea	The sweetness of smoke increased slightly. However, offensive odour was obvious with decreased cleanliness. Overall, there was no obvious positive effects on aroma and smoke.	The sweetness of smoke increased slightly. However, ligneous odour and earthy odour were more obvious with the decreased cleanliness.	The mellowness and matureness of amora, as well as the cleanliness and sweetness of smoke were improved. Besides, combustibility, color and coagulation of ash were also improved.
Raspberry sauce	The matureness and sweetness were improved slightly, but the cleanliness and taste are worse. Besides, thickened protein odour was found.	Ligneous odour was more obvious with the decreased cleanliness and aftertaste.	The nut and bean scents were enriched slightly. However, it shows no significant optimization on the smoke characteristics.
Kvass	The nut, bean and woody scent were weakened, but the plumpness, smoothness, and sweetness of smoke were improved.	The sweetness of smoke increased slightly. Overall, there was no obvious positive effects on aroma and smoke.	The sweetness was improved slightly, but the offensive odor was obvious.
α-amylase	The introduction of α-amylase improved the mellowness, matureness, sweetness, plumpness, and fluentness of CTLs, but also resulted in thickened protein odour.	The sweetness, mellowness, matureness, cleanliness, and fluentness of CTLs were improved, but thickened protein odour was found.	The introduction of α-amylase improved the matureness, smoothness, and sweetness of CTLs, but also resulted in thickened protein odour.
Pectinase	Smoke is soft and delicate. The sweetness and aftertaste were improved. However, thickened protein odour was found.	The mellowness, matureness, fluentness, smoothness, and aftertaste were improved. However, thickened protein odour was found.	The mellowness, matureness, and cleanliness of CTLs were improved. However, thickened protein odour was found.
Flavourzyme	The aroma and smoke characteristics, including mellowness, matureness, fluentness and smoothness were upgraded, and offensive odour was weakened except for protein odour. In fact, thickened protein odour was found.	The aroma and smoke characters, including cleanliness and sweetness were upgraded. However, thickened protein odour was found.	The mellowness, matureness, and aroma richness of CTLs were improved. However, thickened protein odour was found.

water), the relatively low levels of aroma richness and smoke concentration, as well as the obvious offensive odor were found in different CTL samples. It indicated that the Chinese CTLs with different varieties harvested from different producing areas show the common problem of insufficient aroma value and quality, which is the main obstacle for the development of Chinese cigar (Chen et al., 2019; Li et al., 2019). Therefore, it is necessary to enhance the quality of CTLs by adjusting fermentation process. Notably, DX-4 and DX-7 present a better sensory quality than CX-14, indicating that the sensory difference of CTLs from different production areas in China is existed, and the quality of CTLs produced in De-yang is better than that in Shi-yan (Li et al., 2019; Wang et al., 2020).

As shown in Table 1 and Figure 1, the addition of cumin, coffee, cocoa, or ginger significantly enhanced the sensory quality of DX-4 tobacco leaves. These CTL samples show better performances on the plumpness, matureness, fluentness, and aroma richness than the tobacco sample fermented with water. Besides, combustibility characteristics was also improved with the addition of abovementioned additives. Besides of DX-4, DX-7 fermented with coffee, cocoa or ginger also demonstrate enhanced performances on aroma, smoke and combustion characteristics than the control sample. Additionally, coffee, cocoa, and rhodiola rosea could improve the sensory quality of CX-14 tobacco leaves. The additives of ginger and cumin can introduce spicy scent to CTLs, and rhodiola rosea could promote the production of woody and fruit scents, while coffee, cocoa and nut scents were enriched with the addition of coffee or cocoa. Therefore, the flavor richness and values of CTLs were improved. Moreover, with the prominence of the main aroma and the enrichment of auxiliary aroma, offensive odors such as green and protein odors were weakened obviously. It is attribute to the change of metabolic pathway of microorganisms during the fermentation process and the suppression of odors by abundant aroma components (Zhang et al., 2020).

In addition to the abovementioned additives obtained from plants, we found that three enzymes, including α-amylase, pectinase and flavourzyme, could also enhance the sensory qualities of three tobacco leaves. Characteristics of mellowness, matureness, and smoothness of CTLs were improved obviously. The addition of α-amylase could promote the production of polysaccharide effectively, thus improving the sweetness of CTLs (Deng et al., 2022). However, thickened protein odor with the addition of three enzymes could not be ignored, which may be caused by the excessive addition amount of enzyme. Therefore, optimizing the enzyme dosage is a necessary step to enhance the aroma quality of CTLs by using enzyme to strengthen fermentation process. In fact, improving the aroma and sensory quality of CTLs by enzymes is proved for the first time in this study, since there is no report to study the effects of enzymes on cigar fermentation.

In conclusion, several effective additives, such as coffee, cocoa, ginger, cumin, and rhodiola rosea were screen out by sensory quality evaluation. Therefore, the changes of aroma components and other conventional chemical compositions in CTLs with the addition of effective additives were analyzed in the following.

3.2 Major chemical compositions analysis

Several major chemical components in tobacco leaves, including TN, NIC, TS, and RS were analyzed using a continuous flow analytical system. Figure 2a-2c shows the influences of effective additives on the contents of TN and NIC. The contents of TN and NIC were about 3~4% (w/w), which is consistent with a previous report (Liu et al., 2021). TN contents of DX-4 and DX-7 were slightly higher than that of CX-14 in the control group,

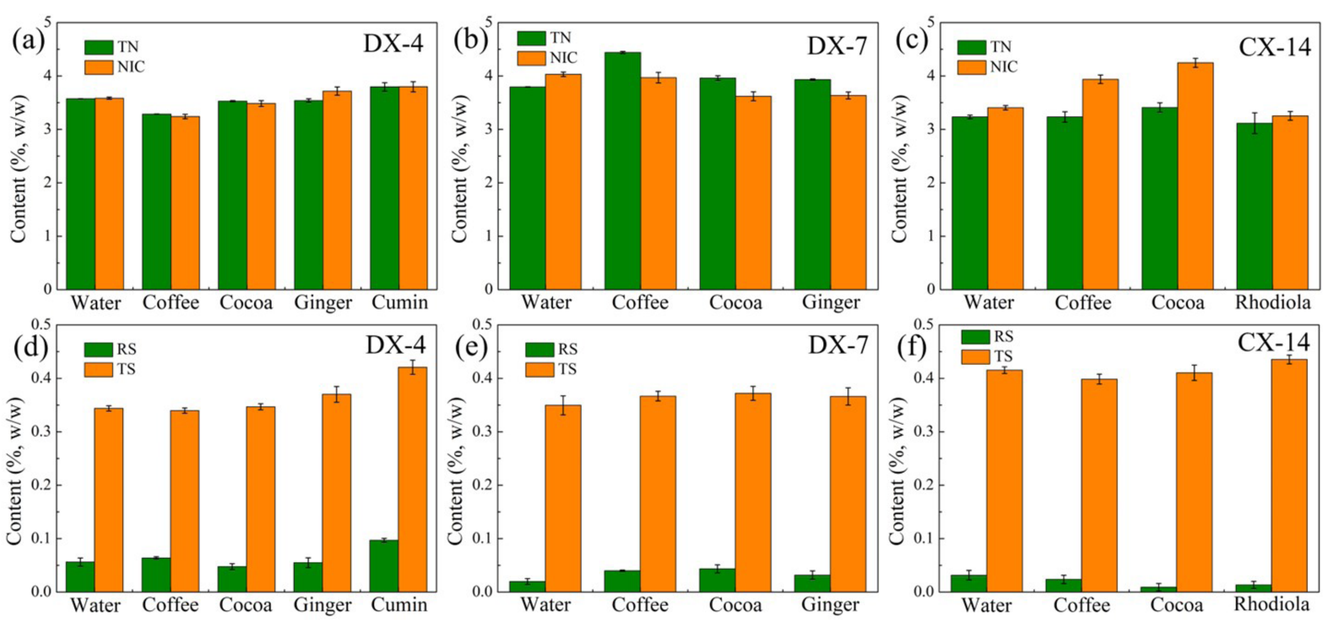

Figure 2. Effects of different additives on the contents of TN, NIC, RS and TS in CTLs. (a) TN and NIC contents in DX-4; (b) TN and NIC contents in DX-7; (c) TN and NIC contents in CX-14; (d) RS and TS contents in DX-4; (e) RS and TS contents in DX-7; (f) RS and TS contents in CX-14.

thus the smoke concentration of CTLs obtained from De-yang was higher than that of samples from Shi-yan. According to the results of sensory quality evaluation, coffee and cocoa both show obvious effectiveness on enhancing the aroma concentration and qualities of these three tobacco samples. However, coffee shows different effects on TN contents of the three tobacco leaves. The addition of coffee could reduce the TN content of DX-4 and increase that of DX-7, but shows no obvious effect on that of CX-14. Besides, coffee and cocoa can increase the NIC content of CX-14, but reduce that of CTLs produced from De-yang. The effects of different media on NIC and TN contents of different tobacco leaves were different, which may be caused by the different chemical compositions of tobacco raw materials (Li et al., 2015).

As shown in Figure 2d-2f, TS contents of the three tobacco leaves were 0.3~0.4%, while the RS contents were all less than 0.1%. Compared with flue-cured tobacco, the sugar content of cigar leave presents a relatively low level (Chen et al., 2017). The addition of several effective additives can increase the TS content in tobacco leaves, but has no significant effect on RS content. At the end of fermentation process, RS is almost completely consumed by biochemical reaction, such as Maillard reaction and caramel reaction (Chen et al., 2022; Li et al., 2022). Therefore, adding amylase could improve the sweetness of tobacco leaf remarkably, which was consistent with the results of sensory quality evaluation.

3.3 Aroma components analysis

The effects of additives on the aroma components in CTLs were analyzed by GC-MS and shown as Table 2-4. As we can see, the total contents of aroma components increased from 2.0398 mg

Table 2. Effects of different additives on aroma components of DX-4.

Components	Content (mg g^{-1})				
	Water	Coffee	Cocoa	Ginger	Cumin
alcohols	0.7438	1.5639	1.5195	1.4063	1.4621
alkenes	0.5147	1.1323	1.8901	1.0458	1.3105
Phenolics	0.2049	0.1679	0.1339	0.1787	0.2449
Ketones	0.2500	0.6668	0.9124	0.4459	0.3677
Esters	0.0343	0.0854	0.1341	0.0538	0.0689
Acids	0.0557	0.2560	0.6045	0.2463	0.2341
Heterocyclics	0.2364	0.4321	0.2171	0.1946	0.1680
Sum	**2.0398**	**4.3044**	**5.4116**	**3.5714**	**3.8562**

Table 3. Effects of different additives on aroma components of DX-7.

Components	Content (mg g^{-1})			
	Water	Coffee	Cocoa	Ginger
alcohols	1.3591	1.3923	1.4581	1.8147
alkenes	1.2824	1.6213	1.5566	1.5447
Phenolics	0.1274	0.1908	0.1323	0.1226
Ketones	0.6881	1.0435	0.8372	0.7033
Esters	0.0709	0.1189	0.0921	0.0639
Acids	0.0564	0.3450	0.2889	0.1030
Heterocyclics	0.2169	0.3182	0.4610	0.1911
Sum	**3.8012**	**5.0300**	**4.8262**	**4.5433**

Table 4. Effects of different additives on aroma components of CX-14.

Components	Content (mg g^{-1})			
	Water	Coffee	Cocoa	Ginger
alcohols	1.3043	1.3703	1.4756	1.5171
alkenes	1.2001	1.2503	1.2109	1.2951
Phenolics	0.0763	0.1246	0.1164	0.1629
Ketones	0.5680	0.7211	0.6745	0.6283
Esters	0.1022	0.0872	0.1641	0.0650
Acids	0.0377	0.1538	0.1837	0.1314
Heterocyclics	0.7253	1.0539	0.6740	0.5698
Sum	4.0139	4.7612	4.4992	4.3696

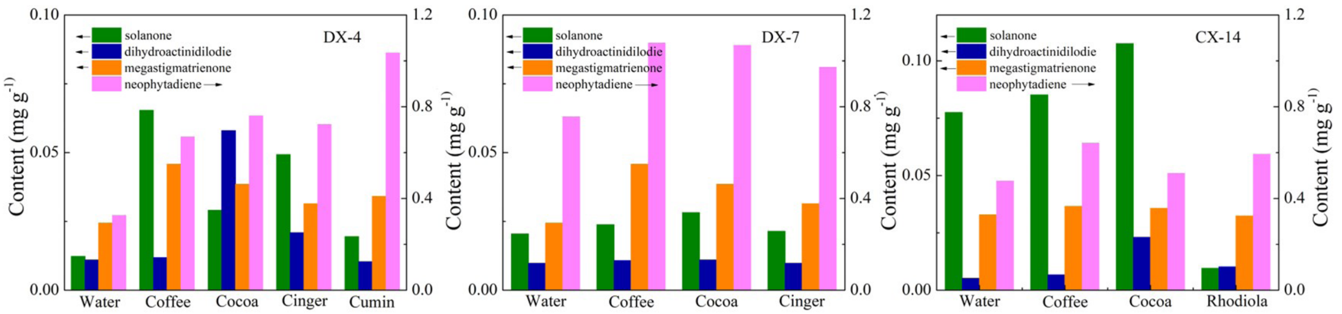

Figure 3. Effects of different additives on several typical aroma components of CTLs.

g^{-1} to 4.3044, 5.4116, 3.5714, and 3.8562 mg g^{-1} in DX-4 with the addition of coffee, cocoa, ginger, and cumin, respectively. The aroma components contents of DX-7 and CX-14 also showed the similar increasing trend, which could improve the aroma values of CTLs effectively. Besides, compared with ginger, cumin and rhodiola rosea, coffee and coco showed the better performance on increasing the total amount of aroma components in CTLs. Based on the sensory quality evaluation results, the enhancement of smoking quality with the coffee or cocoa was higher than that with other additives, which is consistent with the change of aroma components. Moreover, the contents of alcohols, alkenes, ketonic, acid, and ester compounds in DX-4, and alcohols, alkenes, ketonic, and acid compounds in DX-7, as well as alcohols, alkenes, phenolic, ketonic, and acid compounds in CX-14 increased with the addition of these additives. It laid a material foundation for the improvement of tobacco sensory quality.

In addition to the total content of aromatic substances, the contents of several typical aromatic compounds in CTLs were also changed obviously. As the flavoring substance of the highest content and important intermediate compound of chemical reaction in tobacco, neophytadiene not only directly affects the sensory quality of tobacco leaves, but also affects the formation and consumption of other flavoring substances (Shi et al., 2013). Neophytadiene possesses delicate fragrance, which is formed by the degradation of chlorophyll in the processes of maturation and modulation (Wang et al., 2021). Therefore, the degradation of chlorophyll with green offensive odor, as well as the generation of neophytadiene, could promote the improvement of mellowness and the reduction of stimulation. As shown in Figure 3, for DX-4, the introduction of additives increased the content of neophytadiene by 1~2 times. Compared to neophytadiene, megastigmatrienone possesses a relatively low content in CTLs. However, megastigmatrienone contributes greatly to the aroma of cigar. According to previous report, adding 0.01% (w/w) of megastigmatrienone can significantly enhance the quality of cigar (Wu et al., 2013). Besides, megastigmatrienone possesses fruit and tobacco aroma, which usually exists with multiple isomers. In this study, two isomers of megastigmatrienone were detected. The contents of megastigmatrienone increased from 0.0244 mg g^{-1} to 0.0458, 0.0385, 0.0314, and 0.0341 mg g^{-1} in DX-4 with the addition of coffee, cocoa, ginger, and cumin, respectively. The increasement of megastigmatrienone can effectively improve the mellowness, sweetness, and cleanliness of CTLs (Yang et al., 2016). Besides of neophytadiene and megastigmatrienone, other representative aromatic compounds in CTLs, including solanone and dihydroactinidiolide also increased. Solanone has fresh carrot - like fragrance, which can increase the plumpness, mellowness, and smoothness of CTLs (Lin et al., 2022). Only light fruit and baked aromas were emanated from dihydroactinidiolide, but it can weaken the pungency well, thus increasing the cleanliness and mellowness of tobacco leaves (Liu et al., 2013). Therefore, these aroma components can not only directly enrich the flavor of tobacco leaves, but also improve the quality of smoke and aroma characteristics through alcoholizing smoke and reducing pungency.

Apart from the enrichment of self-contained flavoring substances, the additives could also introduce new aroma components into CTLs. Coffee and cocoa contain abundant caffeine and theobromine, respectively, which give tobacco leaves fragrant aroma of coffee, cocoa, and nut (Gutierrez et al., 2022; Mostafa, 2022). It is consistent with the results of sensory quality. Consequently, with the increasing of amount and variety of aroma components, the sensory quality of tobacco leaves was improved.

4 Conclusion

In this study, several effective fermentation additives, including coffee, cocoa, ginger, cumin, and rhodiola rosea were screen out. They could effectively improve the aroma richness, aroma and smoke characteristics, aftertaste and combustion performance of domestic CTLs, so as to optimize the sensory quality of cigars. Among them, coffee and cocoa can enhance the smoking quality of CTLs from different areas. According to the results of major chemical compositions and aroma components analysis, these effective additives can increase the contents of TS, alcohols, alkenes, ketonic and acidic aroma components in CTLs. Besides, the enrichment of several typical aromatic compounds, including neophytadiene, megastigmatrienone, solanone, and dihydroactinidiolide, as well as the introduction of new flavoring substances, were also detected. The changes of chemical compositions and aroma components provide material basis for the increasement of sweetness and flavor richness, thus promoting the enhancement of sensory quality of domestic CTLs.

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